Determination of Composite Material Sensitivity to Permeability Depending Upon Lay-up Configuration

Project Number: 95-05

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Purpose

The purpose of this study is to investigate how the permeability of advanced fiber reinforced plastic (FRP) cryogenic tank structures are affected by fiber orientation (i.e., lamination sequence) at cryogenic temperatures (LN_2 or LH_2) as a function of stress. The study will be performed using carbon fiber reinforced plastic (CFRP) half-tanks or partial domes that are subject to cryogenic temperatures while being pressurized.

Background

The use of composite materials for structures to be used in the future exploration of space continues to increase because of their favorable strength-to-weight characteristics and potential cost effectiveness. The effort to significantly reduce launch vehicle weight while still meeting mission objectives has led to increasing the use of high-modulus, high-strength CFRP materials for major structural elements. This effort is now being extended to cryogenic tankage as newer and better fiber/resin systems are developed that reduce membrane permeability. General Dynamics Space Systems Division (GDSS) has designed and built a single rectangular cryogenic liquid hydrogen tank under the National Aerospace Plane (NASP) program. This tank was constructed from a single fiber/matrix system; therefore, it was not possible to evaluate multiple material systems. The article successfully sustained repeated liquid hydrogen pressures of 22 psi without leakage, and demonstrated that CFRP materials can be used to manufacture cryogenic tankage. Materials properties derived from this effort will be used in the design and analysis of the composite panels and bottles that will be a part of this effort. In addition, Martin Marietta Corp. has worked on the development of CFRP cryogenic tanks with liners as part of the External Tank and National Launch System programs. However, the previous research has not determined, through actual testing, the level of permeability exhibited by CFRP cryogenic tanks subjected to pressure and thermal loads.

Approach

The method for achieving the objectives of this CDDF has changed from the previous annual report. Instead of performing a two-phase study using biaxial test panels in phase 1 and a 5.75-inch-diameter by 18-inch-long test bottle for phase 2, the new approach is to test either CFRP half-tanks using a new test facility or CFRP partial domes at the Cryostat Test Facility (CRF) in the west test area. The testing of the partial domes at the CTF provides a proven test method that has been used on previous CDDF investigations. The only drawback is that the partial domes are 5 feet in diameter and require a significant amount of CFRP material to produce each dome. Thus, the existing funding would allow for the fabrication and testing of only three to four partial domes which will significantly reduce the number of ply

orientations that may be used during the investigation. On the other hand, using the CFRP half-tanks will provide more than enough test articles (≈30–40) with different material systems and ply orientations; however, the test fixture and facility would have to be designed and built. In any event, fabrication of the components will take place at the Productivity Enhancement Center at Marshall using advanced material processing technology.

Accomplishments

Two different CFRP material systems were purchased and are awaiting component fabrication. Four flat panels were fabricated from this material by the former principle investigator (PI) for biaxial testing. Providing time and funding are available, these test panels will be loaded using a biaxial test fixture and then tested for room temperature permeability at MSFC.

Due to the death of the former PI and the recent return from the full-time study program of the current PI, there have been no additional accomplishments to date. A new schedule and method for achieving the objectives of the CDDF have been formulated. Therefore, it is requested that a 2-year, no-cost extension be granted to complete this study. This extension would allow this work to be completed with the results being applicable to the development of the Reusable Launch Vehicle and future launch vehicles.

Planned Future Work

Design, fabrication, and testing of the CFRP half-tanks or partial domes will begin around July 1, 1998. This research will provide crucial information which is presently unavailable for composite cryogenic tanks.

Funding Summary ($k)

FY95	FY96	FY97	Total
92,195	0	82,805	175,000

A funding balance of 0.00 currently exists.

Status of Investigation

The project was approved October 1, 1994, and was scheduled for completion September 30, 1996. A 2-year, no-cost extension is being requested to complete this study.